Spontaneous Mode Selection of Self-Motile Object under Chemical Noneqilibricity

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Modern human activity is largely dependent on the use of heat-engine working under the strict constrain of the second law of thermodynamics. Contrary to this, living organisms on the earth are spending their lives through the usage of isothermal chemical-motor. Nowadays, in order to overcome the environmental problem, people are trying to develop chemical battery, which needs robust electronic shielding. It is obvious the underlining mechanism of chemical-motor in life is substantially different from that of chemical battery. Thus, studies toward the construction of isothermal chemical motor exhibit high scientific importance.

We are currently performing the investigation on the generation of regular motion in a liquid system under isothermal condition. It is well known that interface between different liquid phases shows self-agitation when the chemical compositions are far-from-equilibrium, i.e., chemical Marangoni effect. In the present paper, we show that regular motion is spontaneously induced in a reactive droplet by adopting an appropriate boundary condition.[1-3]

Figures exemplify the experimental observation on the emergence of autonomous motion of a liquid droplet, powered by chemical potential gradient. The spontaneous motion of the droplet is considered as a representation of spatio-temporal structure under thermodynamically open conditions. It is found that various characteristic modes on the spontaneous motion are generated, such as rhythmic translational motion, vectorial motion, revolution, climbing, blebbing, chemo-phoresis, etc. Switching between different modes will be discussed in terms of bifurcation on phenomenological nonlinear differential equations to interpret an active Brownian particle. Such an experimental observation is discussed under a novel hypothesis of machinery working under significantly fluctuating environment.

References

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[2] Y. Sumino and KY, Self-motion of an oil droplet: A simple physicochemical model of active Brownian motion, *Chaos*, Vol. 18, 026106(1-9), 2008.

[3] Y. Sumino, et al., Spontaneous Deformation of an Oil Droplet Induced by the Cooperative Transport of Cationic and Anionic Surfactants through the Interface, *J. Phys. Chem. B*, Vol. 113, 15709-15714, 2009.

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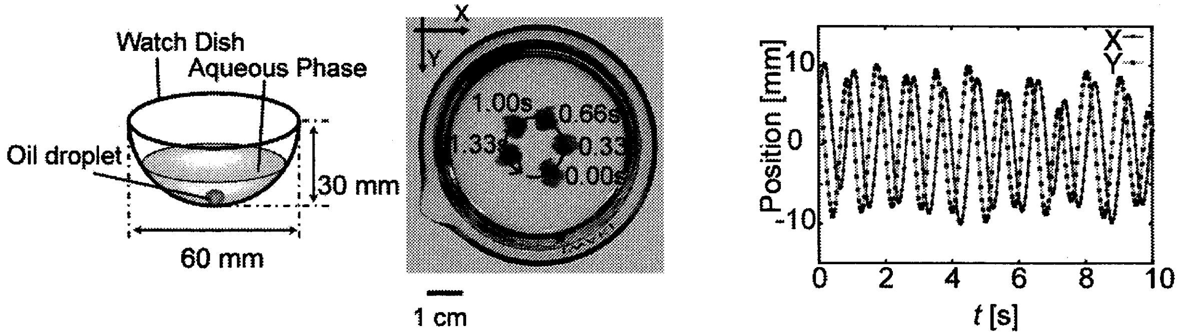

Figure 1: Orbital motion of an oil droplet under water in a round-bottomed vessel. Left; apparatus, Middle; time-successive picture, Right; time-traces. The aqueous phase, 1 mM stearyl trimethyl ammonium chloride, and the organic phase, 5 mM iodine solution of nitrobenzene saturated with potassium iodide, were used.

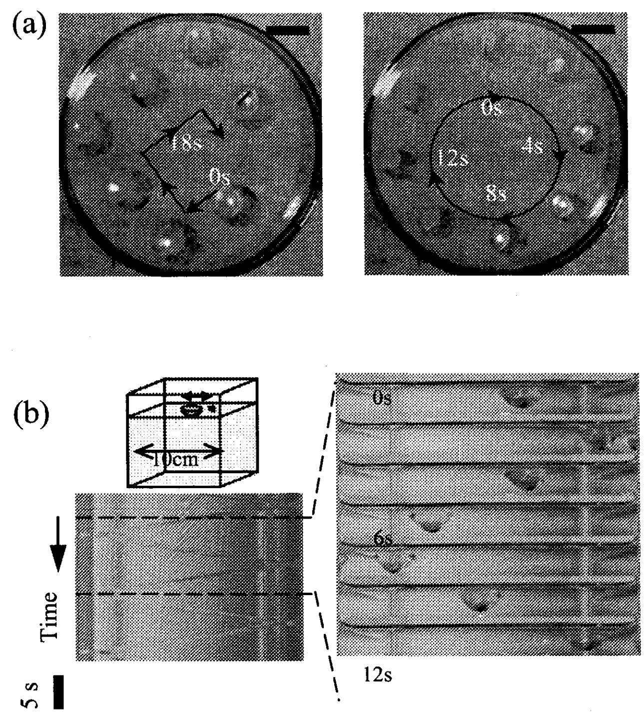

Figure 2: Self-propelled motion of aniline droplets. (a) Spatio-temporal evolution of beeline motion (left) and circular motion (right) in a circular Petri dish. The droplets have volumes of 975 *ml* (left) and 325 *ml* (right), respectively. (b) Spatio-temporal image of beeline motion between two parallel walls in a square vessel. The concentration of the solution in (a) and (b) is 2.8 vol%. Scale bars are 2 cm.

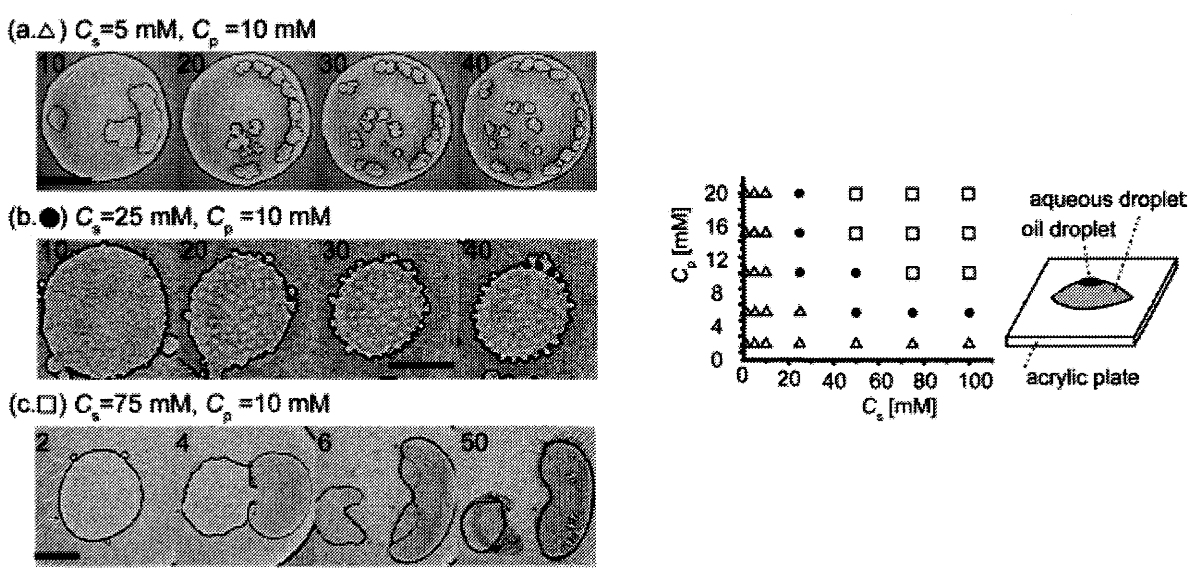

Figure 3: Spontaneous deformation of a tetradecane droplet with palmitic acid (C_p) on an aqueous phase with stearyltrimethylammonium chloride (C_s) is shown. Left: Example of self-propelled motion. Bar: 1cm. Right: Bifurcation diagram and experimental scheme. (Ref. 3)